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(54) **Process and plant for manufacturing hot-rolled strip steel.**

(57) A process for manufacturing hot-rolled steel strip from at least one continuous casting of slabs having a thickness included between 80 and 120 mm at a casting speed from 2 to 5 m/min and at an outlet temperature included between 850 and 1150°C, including also a reheating step of the slab at a temperature suitable for rolling in a transverse re-heating area suitable to act as a "store" between casting and rolling. A plant suitable to carry out said process is also disclosed.

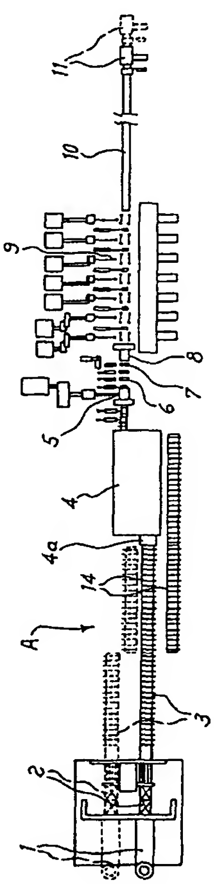

Fig.1

EP 0 665 296 A1

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The present invention relates to a process for manufacturing hot-rolled strip steel, as well as a plant suitable to carry out said process.

For the manufacturing of hot-rolled steel strip from continuous casting various types of process are known, which have developed through the years starting from the so-called "indirect process" which includes:

- continuous casting of slabs 150-250 mm thick.
- Slab cutting at established lengths (generally by oxygen cutting).
- Cold storing of the slabs with inspection thereof and fixing of the defects detected, if any.
- Re-heating of the slabs at a temperature suitable for rolling (about 1250°C) by means of a push-type or walking beam transverse re-heating furnace.
- Rolling of the slabs into bars about 40-50 mm thick by means of a roughing mill of the continuous or reversible type.
- End shearing of the bar.
- Rolling on the finishing mill to obtain a strip of the size requested by the market.

As an alternative to said conventional process, more recently the so-called "direct process" has been used, which essentially differs from the preceding one in that the slab is taken out of the continuous casting and sent still hot into the furnace for a limited re-heating up to the rolling temperature and for the homogenization of said temperature, with apparent advantages of energetic nature.

In more recent times, the so-called "thin slab process" has been developed, which comes from the preceding one and is based on the idea of casting slabs having a thickness (about 50 mm) equal to that of the bar rolled at the roughing mill. This process is substantially made up of the following steps:

- casting a thin slab (about 50 mm).
- Re-heating and temperature homogenization of the thin slab in a longitudinal roller furnace, since the length of the cast product forbids the use of a push-type or walking bean furnace.
- End shearing of the slab.
- Rolling of the strip on the finishing mill to the size requested by the market.

It is true that the thin slab process has energetic advantages with respect to the conventional process, even the direct one, mainly thanks to the elimination of the roughing mill, however it must be noted that said process also gives rise to some problems caused not only by the difficulty in designing a mould suitable for thin slabs, but mainly due to a certain degeneration of the product characteristics. In fact, there is a degeneration of the strip surface quality caused both by the high speeds required to obtain an adequate productivity from a thin casting, and by the problems related to the formation of particularly tenacious scale in the longitudinal furnace. Moreover, it is difficult to cast all kinds of steel, particularly referring to high-carbon steel and stainless steel, while the metallurgical characteristics of the produced strip are not satisfying for certain uses, due to the low rolling elongation ratio, especially with high final thickness. In fact, it is known that the final mechanical characteristics are so much higher as the thickness reduction ratio is higher. Furthermore, in the conventional longitudinal roller furnaces the piece is not heated on the bottom and on the edges, where the greatest thermal losses occur, with a subsequent unevenness of temperature through the thickness and along the length.

Finally, there is a poorly flexible connection between casting and rolling, both in terms of product size variation, especially in terms of width, and in terms of productivity due to the limited store consisting in the longitudinal re-heating section, because of the high length of the slab (not less than 50 m) which also makes difficult the connection between more casting stands. In particular, the lack of an adequate store implies a reduction of the cast productivity during the operations of roller change on the rolling mill, with a further decrease also of the quality level of the slabs affected by the slowing. Vice versa, during the casting stops, also the rolling mill must be stopped thus further reducing the productivity of the line.

Therefore, an object of the present invention is to provide a process that overcomes the above-mentioned drawbacks and problems of the thin slab process while maintaining the energetic advantages inherent in said process with respect to the conventional processes.

The essential characteristics of the process according to the invention are cited in claim 1, while the plant carrying out said process and also being subject-matter of the present invention is defined by the characteristics of claim 7.

Other objects, advantages and characteristics of the present invention will be apparent from the following detailed description referring to the annexed drawings wherein:

Fig.1 shows a schematic top plan view of a plant suitable to carry out the process according to the present invention;

Fig.2 shows, in the same way of fig. 1, a variation of said plant; and

Figs.3a, 3b and 3c schematically show a section of just the portion of plant including the re-heating furnace and the portion downstream thereof, respectively in an execution with direct connection ("mini-tension"), with coil-box connection and in a connection with free bar under panels.

The process according to the present invention is made up of the following steps:

the first operating step of the process according to the present invention is the continuous casting of slabs having a thickness included between 80 and 120 mm. Higher thickness values would imply com-

pactness problems of the plant, while thicknesses lower than 80 mm would present again the drawbacks, particularly the slab quality ones, already previously indicated for the thin slab process. The casting speed is included between 2 and 5 m/min., whereby it is not so high as to compromise the product surface yet allowing a high productivity. The outlet temperature may range from 850 to 1150°C.

After cutting the slabs to the desired length, there is a step of alignment of the slabs on a single production line in case several casting stands are present. At this moment, it is possible to introduce in the re-heating area semi-hot slabs coming from a storage area rather than from the continuous casting, and then re-heat the slab to a temperature suitable for the rolling (up to 1200°C) in a transverse re-heating area that may act as a store between the casting step and the rolling one.

After descaling the slab with hydraulic and/or mechanical means to assure the quality of the rolled product, the pre-finishing rolling to a thickness equal to or lower than 50 mm takes place, then the end shearing of the thus obtained bar, its further descaling and finally the finishing rolling to the desired thickness.

A typical plant suitable to carry out the process according to the invention, described hereinabove in its essential steps, will now be described with reference to the drawings.

Figs.1 and 3 refer to a double continuous casting plant indicated by numeral 1, whose mould has plane parallel sides for thicknesses from 80 to 120 mm. The mould may have variable width so as to assure greater operative flexibility, in particular combined with a tower fitted with independent revolving arms for the quick change of the mould and plunger, in order to allow the greatest compactness of the plant. The mould may also be provided with an oscillator capable of varying the oscillation frequency and stroke during the casting according to the kind of steel and the casting speed.

Referring to point 2 of figs.1 and 2, there is shown the area where the slabs are cut to the desired length, in particular by quick oxygen cutting. The length will obviously be such as to be longitudinally contained within a transverse advancing furnace (about 30 m).

An intermediate area 3 consisting in an insulated rollerway or normalization furnace is followed by an area for the alignment of the slabs, globally indicated by A, which, thanks to the relatively reduced slab length, can include a series of translating carriages 14 which are insulated or consist in lengths of a roller furnace, as shown in fig.1, in order to assure an optimum preservation of the slab temperature and a subsequent energetic saving. As an alternative to this solution, referring to fig.2, the lateral transfer of the slabs may be achieved through a system of transverse furnaces 4', as many as th castings, in particular of the walking beam type same as the successive furnaces, indicated by numeral 4, positioned so as to feed one another in order to provide a good feeding store for the slabs.

It should be noted that in both cases the alignment area A can also include the possibility of admittance for slabs not directly coming from the continuous castings, but for example semi-hot slabs coming from an intermediate storage area.

It should also be noted that area 3, in the case of fig.1 wherein the alignment in A is carried out by means of carriages 14, has a length at least equal to that of a slab, whereas this is not required in the case of fig.2.

In both cases, area A is followed by a re-heating area, with transverse advancing, schematized by numeral 4 and consisting particularly in a walking beam furnace preferably having the inlet and the outlet on opposite sides in the transverse direction, both on a rollerway inside the furnace in order to achieve the optimum compactness of the plant and to assure the shortest permanence of the piece in free air, mostly for energetic saving reasons.

Said furnace 4 will preferably be internally provided with known piece transfer devices, such as to allow independent loading and unloading cycles and thus optimize the utilization of the store between casting and rolling mill. In fact, said method permits to reach a high "storage" capacity between casting and rolling mill in this area, at least twenty minutes, capable of allowing the upkeep of the rolling mill productivity during the casting tools change and the absorption of the full casting productivity in case of cylinders change or short accidental stops of the rolling mill.

A furnace adjustment system capable of heating the slabs lengthwise in a differentiated way may be provided so as to assure the greatest uniformity and constancy of temperature of the piece being rolled. Furthermore, the previously mentioned direct admittance of slabs not directly coming from the casting may be provided at said furnace 4, as an alternative to their introduction in the slabs alignment area A immediately upstream.

Finally, still considering the transverse re-heating area, while in fig.2 furnace 4 is directly fed by furnaces of the same type 4' (walking beam), in fig.1 a scarfing device 4a, e.g. of the torch type, is inserted between carriages 14 of the slabs alignment area A and furnace 4.

Immediately downstream from the transverse re-heating area 4, there is provided a pre-finishing group 5 consisting in one or more rolling stands, whose purpose is to reduce the piece thickness from the original 80-120 mm to less than 50 mm. The number of stands and their type (two-high or four-high) will be selected according to th piece size, and in particular to the starting and final thicknesses. Said pre-finishing

group may be provided with one-way or reversible rolling, i.e. capable of inverting th piece motion so as to carry out more rolling steps with the same stand, thus reducing the number of stands installed downstream. Vertical stands, which are useful for various reasons, may be employed thanks to the values of the thickness entering the pre-finishing group. A first reason is the possibility of calibrating the piece width by adjusting it through an automatic control system according to the desired final width.

Another function of the vertical stands is the mechanical breaking of the scale so as to facilitate the removal thereof by means of hydraulic systems and thus assure a better surface quality. To this purpose, hydraulic descaling devices may be provided between the horizontal and vertical stands.

Moreover, the entrance to the horizontal stand in case of strong thickness reductions is made easier and shaping of the piece head is made possible so as to limit the waste at the moment of the shearing, also reducing the likelihood of stoppage at the entrance guide of the finishing mill.

As far as the connecting area between the pre-finishing group 5 and the finishing rolling mill 9 is concerned, said connection may be accomplished in various ways according to the different production needs. In particular, three connection ways may be provided, respectively schematically illustrated in figs.3a, 3b and 3c.

A first way of direct connection is shown with reference to fig.3a. In this case, the piece is simultaneously rolled at the pre-finishing mill and at the finishing mill, and the piece integrity is preserved by a tension adjustment system acting thereon. This solution assures the greatest plant compactness and the lowest investment cost. It is shown in the layout examples of figs.1 and 2, where in both cases an induction heater 6 for the piece edges, a rotary shear 7 for the end cutting of bars having a thickness lower than 50 mm, as well as a descaler 8 are provided between the pre-finishing group 5 and the finishing rolling mill 9.

A second way of connection through a coil-box 15 is shown with reference to fig.3b. With this solution, the piece is coiled at the outlet of the pre-finishing group 5, turned over at the inlet of the finishing mill 9 and uncoiled to be rolled thereon. The temperature upkeep is assured by the small exposed surface of the coiled piece. This solution, already known, maintains a significant compactness and allows two pieces to be simultaneously rolled respectively at the pre-finishing mill and at the finishing mill. The uncoupling between the two rolling groups also allows the rolling of the piece at an optimum speed for the different steps.

The third type of connection, i.e. the free bar type, is illustrated in fig.3c. In this case the piece leaves the pre-finishing group 5 before entering the first stand of the finishing mill 9. The maintenance of the temperature is assured by insulated panels or by a small roller furnace 16. The advantages of the preceding solution are still present, but the room needed is greater, since a longer layout is required. The main advantage of this solution is that it allows the use of a reversible pre-finishing mill which implies the reduction of the number of finishing passes needed to obtain a certain strip thickness.

The last two solutions, corresponding to figs.3b and 3c, are the most easily adoptable in case of upgrade of conventional rolling mills.

Finally, it should be noted that the finishing mill 9 may be any one of the types presently known, selected according to the production required and to the purpose of assuring the highest product quality. A cooling area 10 and then the downcoilers 11 are provided downstream from the finishing mill.

In the light of the above, the advantages of the process according to the present invention are apparent in that, in addition to assuring a high "storage" capacity between casting and rolling as already previously pointed out, it allows the casting of all kinds of steel, thanks to the slab thickness and to the casting speed, with a high surface quality of the product, still thanks to said speed, as well as to the reduced formation of scales sticking to the piece.

Moreover, a significant flexibility in the piece width variation is obtained, since it is possible to install a variable width mould thanks to the slab thickness which is not excessively reduced.

Furthermore, the transverse furnace provides a better homogenization of the slab temperature and allows a good ease of connection to more casting stands entering the rolling mill with a higher plant use flexibility. Moreover, another advantage is also the possibility of feeding to the transverse furnace semi-hot or cold slabs not directly coming from the continuous casting, said advantage being still greater for those kinds of steel that require a surface inspection and the removal of defects out of the line. On the other hand, the discarding as scrap of material cast merely to exhaust the load in case of significant problems at the rolling mill can be avoided by diverting it to the "stores" provided in the plant.

In addition to resulting more compact, thanks to the transverse re-heating area, the layout can be made modular in view of the increasing productivity levels planned in subsequent steps, thanks to the ease of connection to more lines, while the flexibility may even reach a possible insertion of the first portion of the process onto existing rolling mills operating according to the conventional indirect process, with apparent energetic advantages.

Finally, certainly not the least advantage is the achievement of an elongation ratio sufficient to assure excellent metallurgical characteristics even for high final thickness, with reference to any kind of steel, even stainless and high-carbon steel.

Claims

1. A process for manufacturing hot-rolled steel strip from continuous casting, characterized in that it includes the sequential steps of:
   a) continuous casting of slabs having a thickness included between 80 and 120 mm at a casting speed from 2 to 5 m/min and at an outlet temperature included between 850 and 1150°C;
   b) cutting the slabs to the desired length;
   c) re-heating the slabs at a temperature suitable for rolling, upto 1200°C, in a transverse re-heating area suitable to act as a "store" between casting and the subsequent rolling step;
   d) reducing the slab thickness to a thickness equal to or lower than 50 mm through a pre-finishing rolling step; and
   e) further reducing the thickness to the desired value through a finishing rolling step.

2. A process according to claim 1, characterized in that it also includes a step of alignment of the slabs on a single production line whenever the casting is carried out on several parallel lines.

3. A process according to claim 1, characterized in that it also includes a step of admittance of slabs coming from a storage area rather than from the continuous casting in order to submit them to said re-heating step.

4. A process according to claim 2 or 3, characterized in that said admittance takes place at said step of alignment of the slabs on a single production line, upstream from the re-heating step.

5. A process according to any of the preceding claims, characterized by the further slab descaling step between the above steps c) and d) and /or between steps d) and e).

6. A process according to any of the preceding claims, characterized by an end shearing step between the pre-finishing and finishing rolling steps.

7. A plant for manufacturing hot-rolled steel strip from continuous casting including at least one continuous casting stand (1) with a mould having plane parallel faces for thicknesses from 80 to 120 mm, a subsequent device (2) for cutting the slabs to the desired length and an insulated rollerway (3), characterized in that it subsequently includes a transverse re-heating area (4) consisting in a furnace having a length at least equal to said slab length, a pre-finishing group (5) consisting in one or more rolling stands and a finishing rolling mill (9), a connection area being provided between said two rolling areas (5, 9).

8. A plant according to claim 7, characterized in that it includes an area (A) for the alignment of the slabs upstream from said re-heating area (4) whenever several continuous casting stands (1) are present.

9. A plant according to claim 8, characterized in that said area (A) for the alignment of the slabs consists in a series of insulated translating carriages (14), possibly consisting in lengths of a roller furnace.

10. A plant according to claim 8, characterized in that said area (A) for the alignment of the slabs consists in transverse walking beam furnaces (4') arranged so as to feed one another.

11. A plant according to claim 7, characterized in that it includes also an area for the admittance of semi-hot slabs coming from storage areas independent from the continuous casting stands (1).

12. A plant according to claim 8 and 11, characterized in that said area for the admittance of the slabs coincides with said alignment area (A).

13. A plant according to claim 7, characterized in that said transverse re-heating area (4) consists in at least one section of walking beam furnace with lateral inlet and outlet on a rollerway.

14. A plant according to claim 10 and 13, characterized in that said transverse re-heating area (4) coincides with said series of transverse furnaces (4') which makes up said area (A) for the alignment of the slabs.

15. A plant according to claim 7, characterized in that said connection area between the pre-finishing group (5) and the finishing rolling mill (9) is of the direct connection type, control means being provided for the tension acting on the piece being simultaneously rolled at the pre-finishing and finishing mill.

16. A plant according to claim 7, characterized in that said connection area includes a coil-box (15) with coiling and subsequent uncoiling thus allowing the simultaneous rolling of two different pieces respectively at the pre-finishing and finishing mill.

17. A plant according to claim 7, characterized in that said connection area is of the free bar type, with

the piece leaving the pre-finishing group (5) before entering the first stand of the finishing mill (9), insulated panels or a small roller furnace (16) being provided to maintain the rolling temperature.

18. A plant according to any of claims 7-17, characterized in that it includes one or more descalers (8) downstream from a rotary shear (7) for the end cutting of the bar having a thickness lower than 50 mm in said connection area between the pre-finishing (5) and finishing (9) mill.

19. A plant according to claim 7, characterized in that said continuous casting mould is of the variable width type.

20. A plant according to claim 7, characterized in that said pre-finishing group (5) includes vertical rolling stands.

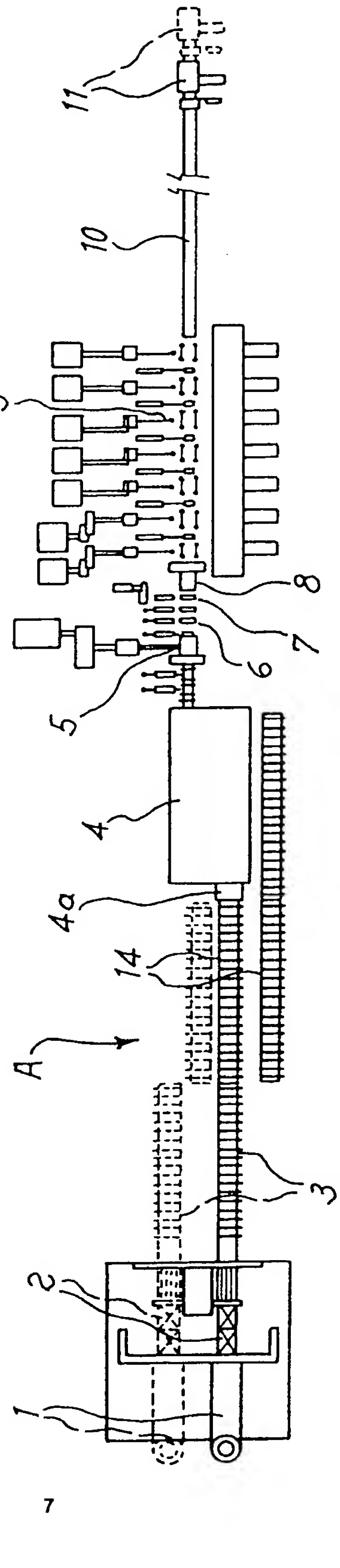

Fig.1

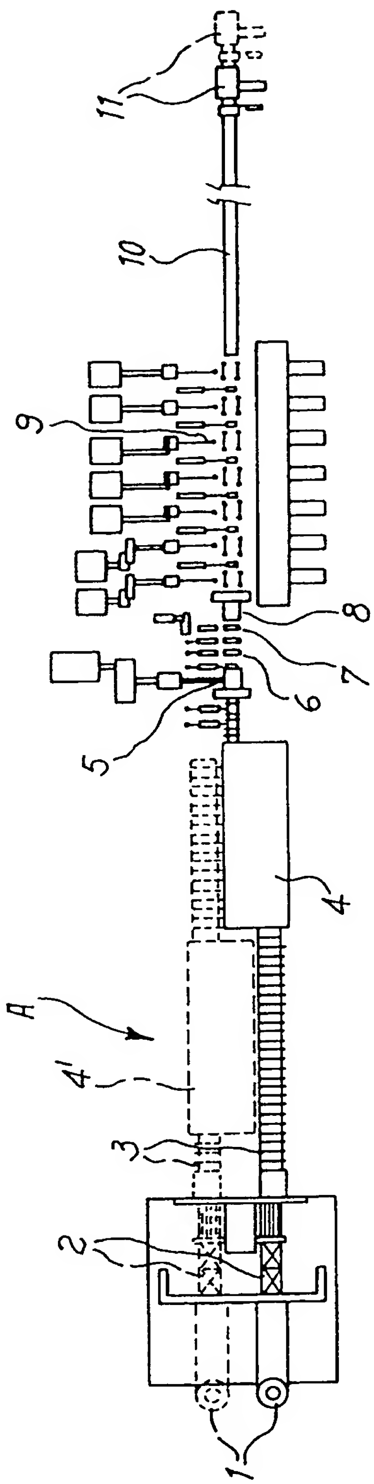

Fig.2

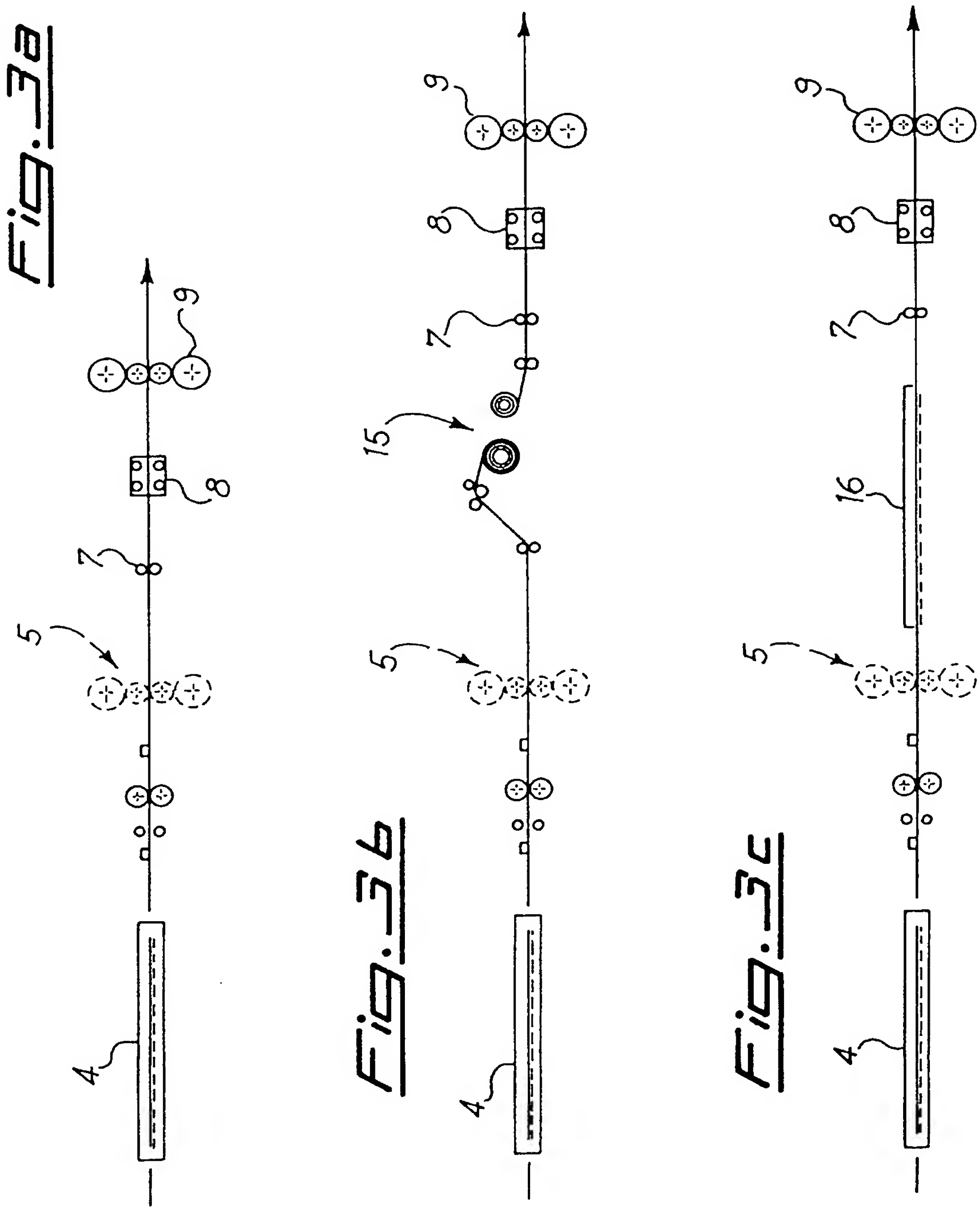

Fig. 3a

Fig. 3b

Fig. 3c

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EUROPEAN SEARCH REPORT

Application Number
EP 95 83 0018

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	HITACHI REVIEW, vol. 39,no. 4, August 1990 TOKYO JP, pages 195-200, T. KIRUMA ET AL. 'Hitachi Mini Hot Strip Mill' * figure 5 *	1-7	C21D9/00 B21B1/46
A	DE-A-33 10 867 (MANNESMANN) * claim 1; figure *	1-3	
A	DE-A-40 41 206 (SMS SCHLOEMANN-SIEMAG) * figure 2 *	2	
A	GB-A-1 594 351 (G.S.K. STEEL DEVELOPMENTS) * claim 1 *	17	
A	US-A-4 170 815 (T. TOKITSU) * claim; figure 1 *	1	
A	EP-A-0 353 487 (DANIELI & C. OFFICINE MECCANICHE) * figure 2 *	1	TECHNICAL FIELDS SEARCHED (Int.Cl.6)
A	PATENT ABSTRACTS OF JAPAN vol. 7 no. 079 (M-204) ,31 March 1983 & JP-A-58 006701 (NIPPON KOKAN) 14 January 1983,	1	C21D B21B
A	DE-A-39 08 457 (LOI ESSEN INDUSTRIEOFENANLAGEN) * claim 1; figure *	1	
A	DE-A-40 17 928 (SMS SCHLOEMANN-SIEMAG)		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	8 May 1995	Sutor, W

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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